Aperture Shield Materials Characterized and Selected for Solar Dynamic Space Power System

Aperture shield sample being installed in a UV-VIS-NIR (ultraviolet-visible-near infrared) spectrophotometer for optical properties evaluation.

The aperture shield in a solar dynamic space power system is necessary to prevent thermal damage to the heat receiver should the concentrated solar radiation be accidentally or intentionally focused outside of the heat receiver aperture opening and onto the aperture shield itself. Characterization of the optical and thermal properties of candidate aperture shield materials was needed to support the joint U.S./Russian solar dynamic space power effort for Mir.

The specific objective of testing performed at the NASA Lewis Research Center was to identify a high-temperature material with a low specular reflectance, a low solar absorptance, and a high spectral emittance so that during an off-pointing event, the amount of solar energy reflecting off the aperture shield would be small, the ratio of solar absorptance to spectral emittance would provide the lowest possible equilibrium temperature, and the integrity of the aperture shield would remain intact.

An off-pointing event is defined as an event where the focused light from the solar dynamic concentrator moves away from the aperture opening of the heat receiver and onto the aperture shield itself. Such an event would cause a considerable amount of solar energy to impinge on a small area. This area, which is expected to heat rapidly, must be made of a high-temperature material that can withstand temperatures above 2000 °C. The surface finish of the material must be diffuse so it does not reflect energy back to the concentrator. Likewise, the surface must have a low ratio of solar absorptance to spectral emittance in order to minimize heating of the structure. Given the low-Earth-orbit application, the surface must also be durable to atomic oxygen exposure.

Over 50 samples of high-temperature materials, including grit-blasted molybdenum, tungsten, and rhenium, were evaluated in collaboration with AlliedSignal Inc. of Torrance, California. Spectral reflectance was obtained with a Perkin-Elmer Lambda-9 spectrophotometer equipped with a 150-mm-diameter integrating sphere. Total and diffuse reflectance were obtained from 250 to 2500 nm, and the data were convoluted into the air mass zero solar spectrum to obtain solar integrated values. Specular reflectance was obtained by subtraction. The solar absorptance was calculated by subtracting the integrated solar total reflectance from unity. Emittance was estimated from the spectral data with the use of a computer program to integrate the reflectance data into blackbody curves at elevated temperatures.

Only grit-blasted tungsten met all of the optical requirements for the off-pointing event on the aperture shield. Hence, selected samples of the grit-blasted tungsten were further exposed to a simulated atomic oxygen environment in a radiofrequency plasma asher, and to 2000 °C in a high-temperature vacuum furnace. Acceptable optical performance was observed after both of these exposures. As a result of the testing, grit-blasted tungsten foil combined with grit-blasted tungsten screen were identified as the materials of choice and were selected for constructing the aperture shield for the solar dynamic power system to be installed on space station Mir.